SICHERHEITSWERK · TRANSDISCIPLINARY PAPER

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Accident and Personal Protection in Additive Manufacturing

A transdisciplinary hazard taxonomy: electrical, chemical, mechanical, biological – across processes, operations, sectors and materials

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Note

This paper describes the state of the art (June 2026) transdisciplinarily and is not legal advice.

It complements the occupational-safety handbook with a systematic hazard-class view. Schichtwerk is a contract manufacturer; implementation responsibility rests with the employer.

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1. Introduction: a transdisciplinary view

Safety in additive manufacturing is often treated in fragments – emissions here, machinery law there. In reality, hazards from several disciplines overlap at a single printing workstation: electrical engineering, chemistry, mechanical engineering and biology. This paper organizes accident and personal protection along a coherent hazard taxonomy and then differentiates it by process, operation/sector and material.

Methodologically, the risk assessment follows the basic machinery-safety system of ISO 12100 (identification, risk estimation, evaluation, reduction in the order design – technical safeguards – user information), complemented by the industrial-hygiene STOP hierarchy. [1]

Keywords: *accident protection; personal protection; hazard taxonomy; additive manufacturing; electrical/chemical/mechanical/biological hazard; risk assessment; PPE; transdisciplinary*

2. System of Hazard Classes

The following taxonomy structures the entire paper. Four main classes (electrical, chemical, mechanical, biological) are complemented by three cross-cutting classes (thermal, optical/radiation, ergonomic/psychological).

Class	Primary source	Lead quantity / effect
Electrical	mains, PSU, heated bed, laser driver	shock, fire, ESD
Chemical	filament/resin emissions, solvents	inhalation, sensitization
Mechanical	moving axes, post-processing	crushing, cut, pressure
Biological	bioprinting, germs in baths, biofilm	infection, contamination
Thermal (cross)	nozzle, heated bed, tempering	burns
Optical (cross)	UV curing, laser	eye/skin damage
Ergonomic (cross)	supervision, fine work	strain, stress

3. Electrical Hazards

Desktop 3D printers contain power supplies (often 24 V DC from 230 V AC), high-current heater cartridges and heated beds, and stepper drivers. Fire events are documented: thermal-runaway incidents from defective heater cartridges, inadequate terminal connections or firmware without thermal-runaway protection are among the most common causes of damage in the FDM field. [2]

3.1 Hazard profile

- Direct/indirect contact with live parts (open PSU, damaged cables).
- Fire from thermal runaway (heater cartridge, loose screw terminals, MOSFET defect).
- Electrostatic discharge (ESD) – especially with powder/resin handling and in dry environments; ESD is also an ignition source for IPA vapours.
- Laser driver electronics (CO_2/diode laser) with high voltage.

3.2 Protective measures

Electrical protective measures

Devices with thermal-runaway protection and tested PSU (CE, IEC 60335/62368); RCD/GFCI.
Fire-safe placement (not on flammable surface, free-standing), smoke detectors, print farm with shutdown concept.
ESD measures: earthing, conductive floors/containers for powder/IPA; observe humidity.
Regular testing of portable electrical equipment.

4. Chemical Hazards

The chemical hazard class is covered in detail in the occupational-safety handbook; in brief here: FDM emits ultrafine particles and VOC (styrene from ABS/ASA, caprolactam from nylon), photopolymers contain skin-sensitizing (meth)acrylates (H317), isopropanol is fire/explosion-prone. The basis is the CLP and REACH regulations and the limit-values ordinance. [3]

- Inhalation: source extraction, HEPA H13 + activated carbon, enclosed chamber.
- Dermal: nitrile/butyl gloves, skin-protection plan; (meth)acrylate sensitization is permanent.

- Fire/explosion IPA: flash point 12 °C, earthed containers, explosion protection (cross-ref electrical/ESD class).

5. Mechanical Hazards

3D printers are machines; the mechanical hazard assessment follows ISO 12100 and Machinery Regulation (EU) 2023/1230 (from 20 Jan 2027; until then Directive 2006/42/EC). Relevant hazards are crushing and shearing points of moving axes, draw-in points, and cut/puncture injuries during post-processing. [4]

5.1 Sources of mechanical hazard

Phase	Hazard	Measure
Printing	moving axes, bed lift	enclosure, door interlock
Resin handling	splashes, sharp build plate	drip protection, gloves
Removal	spatula, cutter	cut-resistant gloves, jig
Post-processing	sanding, milling, compressed air	goggles, extraction, hearing protection
Maintenance	pinch points, springs	energy isolation (LOTO)

6. Biological Hazards

Biological hazards are low in classic plastics AM but are gaining importance: (a) in bioprinting with living cells/hydrogels (biological agents under the relevant ordinance; sterility, risk groups), (b) through microbial contamination of wash, water and IPA baths and water-cooled laser systems (biofilm, Legionella risk in standing water), (c) at food contact through colonization of the rough, porous FDM surface. [5]

6.1 Protective measures

- Bioprinting: biosafety cabinet of appropriate class, aseptic technique, biological-agent assessment, risk-group assignment, disinfection.
- Baths/cooling water: regular change, no standing water, biocide/cleaning, Legionella prevention.
- Food contact: smooth/sealed surfaces, single use or certified materials (EU 1935/2004, 10/2011); rough FDM parts are critical.

Cross-cut biological × chemical

Antimicrobial additives (e.g. silver, copper) shift the hazard profile back to chemical-toxic – assess effect and limits separately.

IPA is itself microbicidal but does not protect against biofilm in diluted/exhausted baths.

7. Differentiation by Process

Process	dominant classes	specific
FDM/FFF	chemical, thermal, electrical	UFP/VOC, bed fire
SLA/DLP/MSLA	chemical, optical	acrylates H317, UV, IPA
SLS/MJF (powder)	chemical, electrical(ESD)	dust/explosion risk, powder handling
DMLS/metal	chemical, thermal, explosion	reactive metal powders (Ti/Al), inert gas
Bioprinting	biological, chemical	sterility, biological agents

Schichtwerk operates FDM and SLA as well as lasers (CO_2/diode); powder and metal processes are not in the portfolio but are listed here for completeness.

8. Differentiation by Operations and Sectors

Setting	main risk	protection focus
Home/hobby	fire, poor ventilation	enclosure, CO/smoke detector
Education/school	pupils, many devices	supervision, low-emission materials, DGUV 202-103
Workshop/contract	continuous operation, post-processing	extraction, PPE, assessment
Medical/dental	biocompatibility, sterility	validated materials, hygiene
Industry	powder/metal, scaling	explosion protection, inerting, measurement

9. Differentiation by Materials

Material	lead hazard	note
PLA	low (lactide)	low-emission, residual fire risk
ABS/ASA	styrene (chem.)	extraction mandatory
Nylon/PA	caprolactam	store dry, ventilate
CF/GF composite	fibre dust (mech./chem.)	sand with extraction, P3
Photopolymer	acrylate H317 (chem.)	gloves, UV, curing
Metal powder	explosion/toxicity	not in portfolio; inert gas
Bio-hydrogels	biological	aseptic technique

10. Personal Protection: PPE by Hazard Class

Class	PPE	standard (example)
Chemical (vapours)	type A respirator	EN 14387
Chemical (particles)	P2/P3 filter, FFP2/3	EN 143 / EN 149
Chemical (dermal)	nitrile/butyl gloves	EN ISO 374
Mechanical	cut-resistant gloves	EN 388
Optical (UV/laser)	goggles/laser eyewear	EN 166 / EN 207
Electrical	insulated tools, earthing	IEC 60900
Biological	protective gown, biosafety cabinet if needed	EN 14126

11. Accident Protection: Prevention, Emergency, First Aid

- Prevention: risk assessment (ISO 12100 + STOP), safe design, instruction, recurring inspection.
- Emergency organization: fire extinguisher (suitable class, class D for metal), eyewash, fire blanket, emergency stop, escape routes.
- First aid: eye irrigation for resin/IPA, skin cleaning, cooling for burns, for electrical accidents self-protection/isolation.
- Reporting and documentation of near-misses; feedback loop into the assessment.

12. Transdisciplinary Synthesis

The strength of the taxonomy lies in the cross-references: ESD (electrical) becomes an ignition source for IPA vapours (chemical); antimicrobial additives (biological) shift to chemical-toxic; fibre dusts from composites are simultaneously mechanical (injury) and chemical (inhalation). Effective protection arises not from isolated measures per discipline but from an integrated assessment that captures these couplings. The hierarchy always remains: eliminate the hazard at source (design/substitution) before technical protection before organization before personal protective equipment.

Core message

A 3D-printing workstation is a multidisciplinary hazard system. Looking at only one class misses the couplings – and thus the most dangerous pathways.

Declarations

Conflict of interest: The author operates Schichtwerk, a service company in additive manufacturing. This work reflects the published state, without external funding.

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References

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[3] Stephens B et al. Atmos Environ. 2013;79:334–339; Byrley P et al. Sci Total Environ. 2019;655:395–407; Verordnungen (EG) 1272/2008 (CLP) und 1907/2006 (REACH).

[4] Maschinen-Verordnung (EU) 2023/1230 (ab 20.01.2027; bis dahin Maschinenrichtlinie 2006/42/EG). Amtsblatt der EU.

[5] Verordnung biologische Arbeitsstoffe (VbA, AT); Murphy SV, Atala A. 3D bioprinting of tissues and organs. Nat Biotechnol. 2014;32(8):773–785; Leitlinien zur Legionellen-Prävention in technischen Wässern.

[6] EN ISO 374 (Schutzhandschuhe Chemikalien), EN 388 (mechanische Risiken), EN 149 (FFP-Atemschutz), EN 166 (Augenschutz), EN 207 (Laser-Augenschutz), IEC 60900 (isolierte Werkzeuge). CEN/IEC.

[7] Schichtwerk. ARBEITSSCHUTZWERK – Arbeitssicherheit in der additiven Fertigung (Vollfassung). Wien; 2026 (Schwesterdokument, AUVA-Rahmen).